Land snails and human impact: temporal resolution of Holocene assemblages

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The Mediterranean World Environnement and History

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1. Introduction

Terrestrial gastropods are good indicators of environmental changes (Goodfriend, 1992; Puisségur, 1976). They are dependent locally on the structure of the vegetation and also, but on a different scale, on the structure of the landscape (Magnin, 1991). Consequently, they seem to be useful tools for the identification and characterisation of the human impact during the Holocene, from the analysis of the composition of snail assemblages collected in sedimentary sequences. However, as these small animals have a low-dispersal ability, they are strongly dependent on their local environment, and they could be presumed to respond with some delay to ecological disturbances. For this reason, the temporal and space resolutions are major problems for the interpretation of land snail assemblages (Thomas, 1985). We will consider here only the issue of the temporal resolution, which involves two series of processes, one ecological and the other taphonomic, which affect communities and assemblages in the course of time (*Fig. 1*).

(1) As for the ecological processes, it is necessary to wonder whether land snails record the human disturbances well and what the rate of response of communities to these disturbances is.

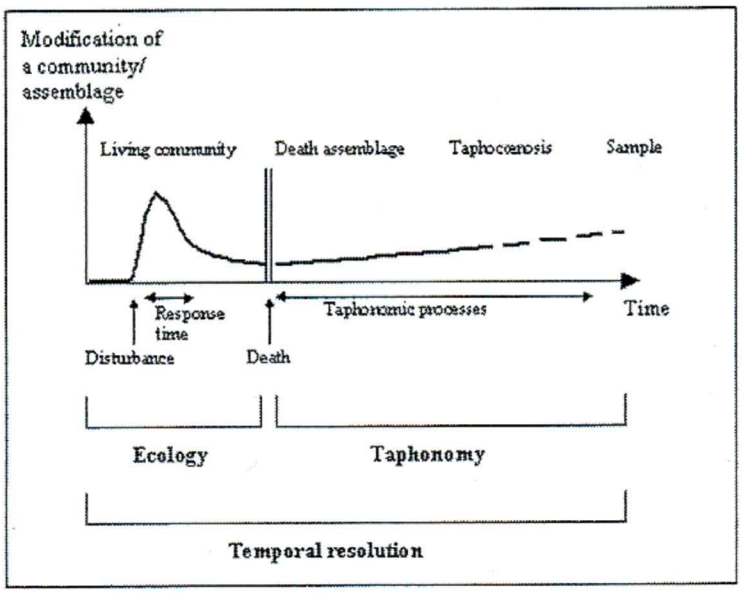


Fig. 1. Ecological and taphonomic aspects of temporal resolution of mulluscan assemblages.

The chronological context, which interests us, the Holocene, is defined by many authors as being a meso-scale of observation (Delcourt and Delcourt, 1988; Dincauze, 1987), during which shorter and more local micro-scale events take place. We will thus examine the snail response to three different levels of environmental changes included in the Holocene meso-scale (Thomas, 2001): a single event lasting a few hours or days (a fire); an event recurring over a few months or years (recurrent fires); a disturbance lasting several decades or one century (cultivation and secondary succession).

(2) As for the taphonomic processes, the taphonomy can restrict the representativeness of land snail assemblages. It implies the transfer of living communities to a death assemblage and then to a taphocœnosis (Roger, 1974) with a loss of information (Birks and Birks, 1980; Roger, 1974), due to mechanical, chemical and biological factors acting directly on the shells (e.g. differential preservation of species (Evans, 1972)) or on the sediments (compaction, erosion, etc.). Therefore, the assemblages are not exact replicas of living communities (Thomas, 1985). Except for the theoretical analysis of Carter (1990), who suggests that there is a weak temporal resolution of molluscan assemblages in buried soils, malacologists (Evans, 1972; Thomas, 1985) generally agree on a good representativeness of the assemblages compared with living communities. From an experimentation in a present-day landscape, we will try to bring about new elements on this issue.

Ecological interpretations of land snail assemblages are based on the assumption that they reflect only one habitat (Carter, 1990), which replies that the factors influencing the formation of death assemblages remain constant over each period (Gee and Giller, 1991). However, an assemblage can also correspond to several communities, either following each other (Sparks, 1964), or living at the same time (Thomas, 1985). There are thus two possible interpretations of a subfossil molluscan assemblage, which we will examine in the last part of this paper in which we try to apply the deductions we have made from the study of the present-day pattern to a Holocene sequence.

2. Rates of response of land snail communities to present-day human disturbances

2.1. From human disturbances to landscape: some ecological concepts

The word "anthropisation" inconveniently includes very different types of human impacts, i.e. connected to the use by man of his environment. In the present work, we will approach anthropisation through what ecologists call "disturbances". Disturbances can be defined as events, separate in time, which modify a population, a community or a landscape, and which change its structure, physical environment and functioning (Dajoz, 1996). It is difficult to consider separately the temporal and the spatial dimensions of the disturbances. At a strictly local level, two temporal aspects are to be examined: (1) the progress of the "succession", which is the process by which a naturally or artificially perturbed ecosystem begins spontaneously to reconstruct, that is, in a sense, a replica of its initial state (Blondel, 1979), and (2) the regime of disturbances (disturbances whose impact on the ecosystems depends on their frequency). But this notion of "regime of disturbances" cannot be separated from that of "landscape" or "metaclimax". We will use here the latter term, hoping that the reader will not be puzzled by the term "climax" which evokes a concept which is known to be smeared with a certain "fixism". According to Blondel (1986, 1987), the "metaclimax" includes all the successional sub-systems, all out of phase with one another, but all equally necessary for the functioning of the whole system on the landscape level. On the level of a woodland landscape, for instance, the regional regime of disturbances activates, in time and in space, a series of local successions whose recurrence and intensity are more or less predictable: the forest is thus a heterogeneous landscape formed by successions at different stages of their development. This concept is particularly interesting in palaeoecology: we will indeed see that molluscan assemblages in a forest metaclimax, including at the same time woodland species and open ground species, can correspond either to an in situ accumulation of several successional stages or to a relatively instantaneous recording of the spatial heterogeneity of the landscape (*Fig. 2*).

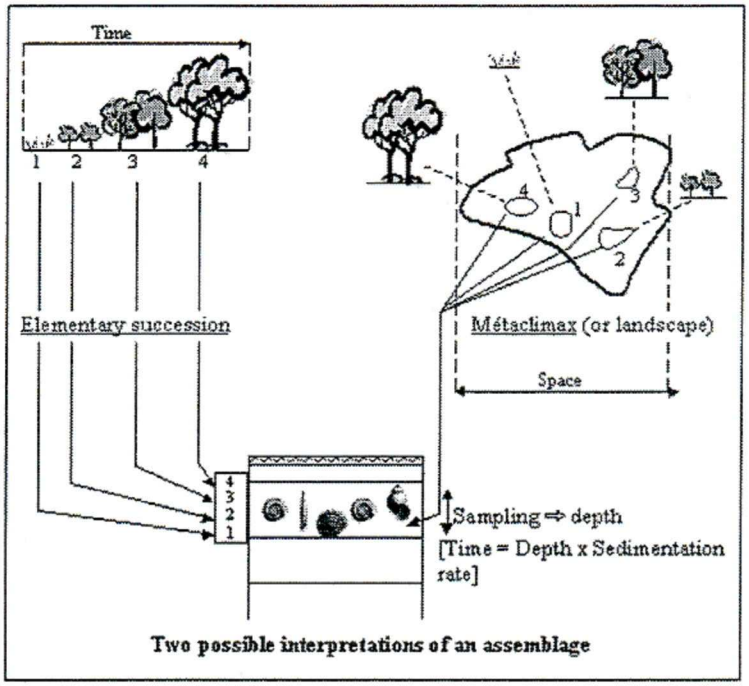


Fig. 2. Temporal vs. spatial resolution of a land snail assemblage.

2.2. Disturbance recording by land snails: present-day fires

To observe if terrestrial molluscs well record short events, we will take as an example the studies about present-day fires in Provence. Fires are a major disturbance in Mediterranean ecosystems. They particularly affect land snails by modifying the structure of their habitat (Kiss and Magnin, 2002), because snails live mostly on the vegetation and in the litter (Ellis, 1969; Janus, 1982). Moreover, the ability of terrestrial molluscs to escape is almost negligible, and their aptitude for dispersal is generally low (Cameron et al., 1980; Baur and Baur, 1990).

However, it can be noted (*Fig. 3*) that during the first 3 years after the fire, the abundance of land snails decreases markedly whereas it begins to stabilise 5 years after the fire. No succession is noted and the snails appear to be more sensitive to vegetation structure than to fire age (Kiss and Magnin, 2002).

One fire disturbance seems to little affect the snail communities in the medium-term. The landscape heterogeneity, created or maintained by this disturbance, does not allow the ecosystem to get back to its original state.

On the contrary, land snails record quite well disturbances recurring with a high frequency, such as the present-day fires in the Mediterranean area. The age of the last fire, the number of fires and the short time-span between successive fires have an impact on the molluscan composition (*Fig. 4*). Between two successive fires, time-span shorter than 10 years favour more xerophilous and anthropophilous species. However, for more than two fires the effects on the composition of the assemblages seem to be less important. Much more than the number of fires, the time-span between two successive fires appears decisive.

Terrestrial gastropods record short events, provided that those are more and less recurring and that the malacological communities are subjected to a significant regime of disturbances.

2.3. Cultivation and secondary successions

In its most primitive shape, cultivation should have consequences of the same order as those of fires. An itinerant cultivation on burnt land, for instance, is likely to preserve a strong spatial heterogeneity combined with a low frequency of disturbances. On the contrary, a cultivated field, as we know it today in our western agricultural systems, consists in the

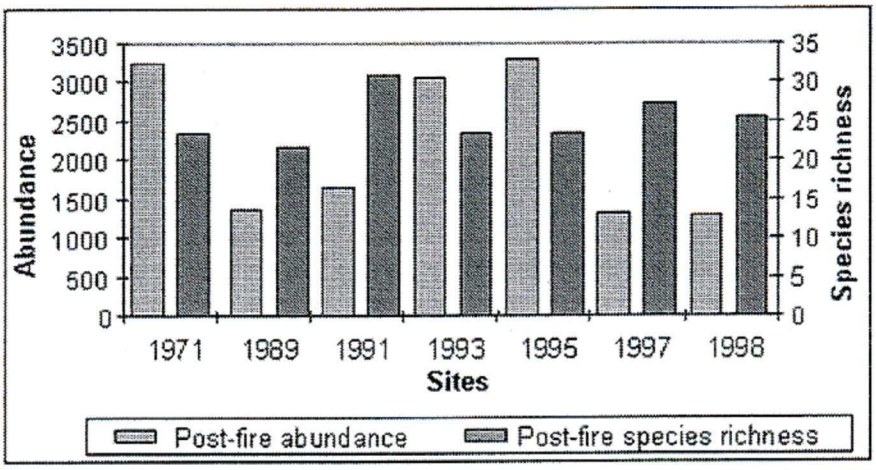


Fig. 3. Individual abundance and species richness of recolonising land snails in 2000, according to fire age (sites located in Bouches-du-Rhône).

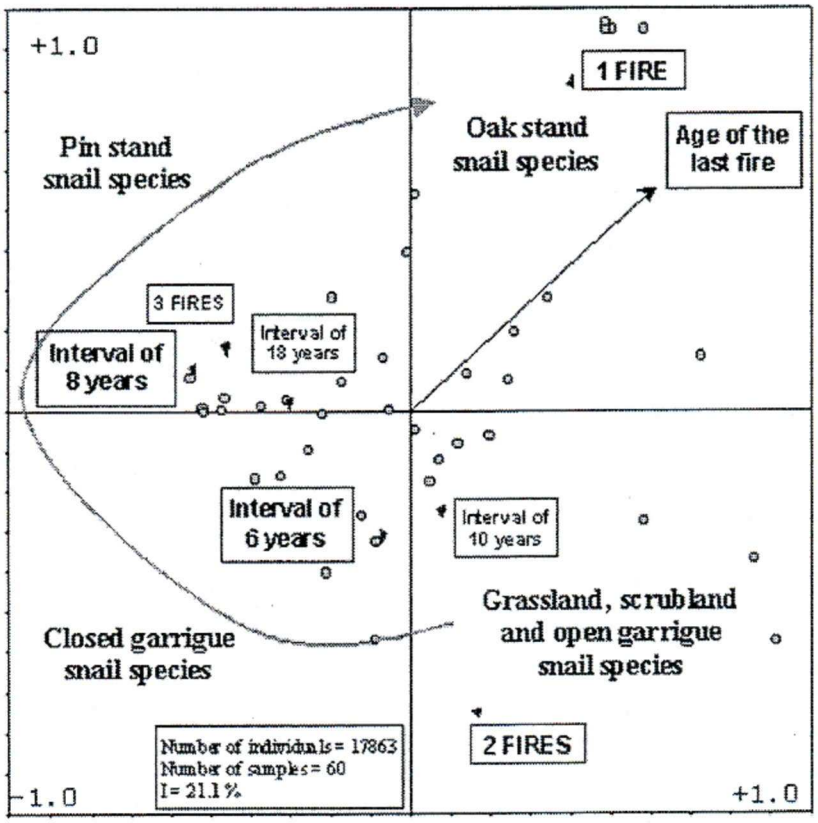


Fig. 4. Canonical Analysis performed on terrestrial gastropods – sample matrix, constrained by fire variables (the significant variables are circled). Sites located in Bouches-du-Rhône.

destruction of all or the most part of the spontaneous vegetation, and in its replacement by more or less mono-specific plantations. As it is very dependent on the structure of the vegetation, the molluscan fauna will be all the more deeply modified since the ground will be stripped bare.

In the field, the destruction of land snails by ploughing is immediate and almost total. The plantation that follows can be accompanied with the re-colonisation by land snail communities whose composition will depend especially on the nature of the cultivation and the size of the land parcel. After this radical rejuvenation of the ecosystem, the land abandonment marks the beginning of a secondary succession. This was studied in Languedoc and in Provence (André, 1981; Magnin and Tatoni, 1995; Magnin et al., 1995) and these studies show a good correlation between the recovery of the flora and that of the malacofauna, so much that both these two biological indicators show the same dynamic gradients. The malacofauna is, however, more sensitive to the structure of the vegetation, a cover of at least 50% being a decisive threshold allowing the installation of typical woodland communities. From a temporal point of view, one can observe a good relationship between the molluscan successions and the age of land abandonment, in spite of some exceptions, which can be due mainly to the situation of the land parcels and to the structure of the landscape. Generally, woodland vegetation and malacofauna are reconstructed after 80 years of abandonment. The detailed schemes are more complex, and analyses at the scale of the landscape and at the scale of a century show that the history of the landscape structure influences significantly the composition of present-day land snail communities.

3. Taphonomic processes: experimentation in a present-day landscape

The recording of vegetation successions by terrestrial gastropods has previously been considered using synchronic analysis, which define a posteriori different stages of evolution of the succession and reconstitute them (André, 1981). We will now use diachronic analysis, which allow the direct observation of the modifications that occurred in the selected environment in time (André, 1981) and the assessment of the taphonomic processes.

With an experimentation on present-day and sub-modern assemblages, we want to compare the well documented recent evolution of a landscape with the molluscan assemblages contained in the different soil horizons. The method is relatively similar to that of Fitch and Lokke (1956), applied in Kansas (USA), which is the only recorded experimentation of this kind we can find.

3.1. Study area

The small valley of La Tapy (3 km long) is located in Saumane-de-Vaucluse (Vaucluse), on the western side of the Monts de Vaucluse. It is drained by an intermittent stream. Its slopes are covered with ancient field terraces. The site has suffered to a dramatic land abandonment since the middle of 19th century. The present-day vegetation is dominated by coppices of *Quercus ilex* and *Pinus halepensis*.

3.2. Materials and methods

Four cadastral surveys (Hostein, 1990; Liberali, 1995) enabled us to observe the evolution of land use in the valley since 1829, parcel by parcel. The Tapy valley, cultivated in gardens and fields of olive-trees and cereals during the 19th century, had been deserted gradually, at first from the margins, since World War I. This abandonment had increased after World War II to become total in 1980.

Seven parcels were selected according to a typology of land use evolutions (time of abandonment, sequences of types of use and topographic position) (*Table 1*).

In each field, the litter and the horizons of the soil were sampled (*Fig. 5*) according to the stratigraphy, as far as the substratum (Miocene molasse), which was quickly reached (at a depth of 0.30 and 0.45 m). For each shell collected according to the traditional method of malacological sample treatment (Puisségur, 1976), it was noted whether it was a living individual (presence of the desiccated animal in the shell), a fresh one (shiny shell, with periostracum) or an "old" one. The determination and the ecological interpretation of the shells were carried out according to the work of Kerney et al. (1999).

3.3. Results and discussion

3.3.1. Recording of land abandonment by terrestrial gastropods

Data including 33 samples and 50 land snail species were analysed by a correspondence analysis (CA) (Benzécri, 1984; SLP Statistique Jambu, 1994). Only

Table 1. Land use evolution of the seven selected parcels (small valley of La Tapy, Saumane-de-Vaucluse), from cadastral surveys.

Samples		*Tapy 1*	*Tapy 2*	*Tapy 3*	*Tapy 4*	*Tapy 5*	*Tapy 6*	*Tapy 7*
Landscape evolution from cadastral surveys	1975-1981	wood	wood	wood	wood	wood	wood	wood
	1944-1955	scrubland	wood	garden	wet meadow	heath	wood	olive-trees
	1911-1915	land	wood	ploughed land	ploughed land	land and olive-trees	scrubland	land and olive-trees
	1829	land	wood	ploughed land	ploughed land	land and olive-trees	meadow	land and olive-trees

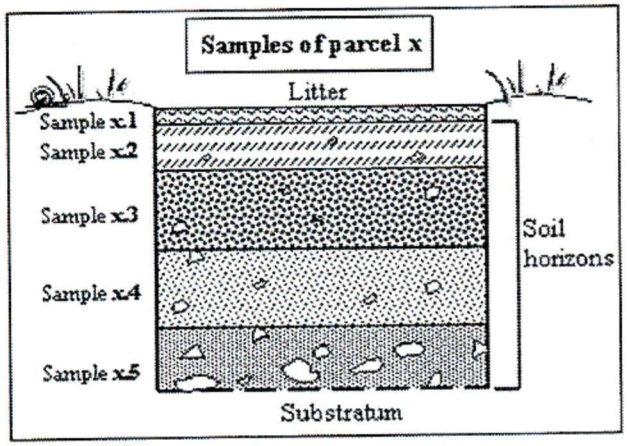


Fig. 5. Method for the diachronic experimentation on the small valley of La Tapy (Saumane-de-Vaucluse).

the living and fresh individuals were taken into account for the litter samples whereas only the "old" individuals were considered in the lower levels. This CA involved 10,507 individuals. The first factorial plane represents 39.55% of total inertia (27.69% for the first axis and 11.86% for the second axis) (*Figs. 6 and 7*).

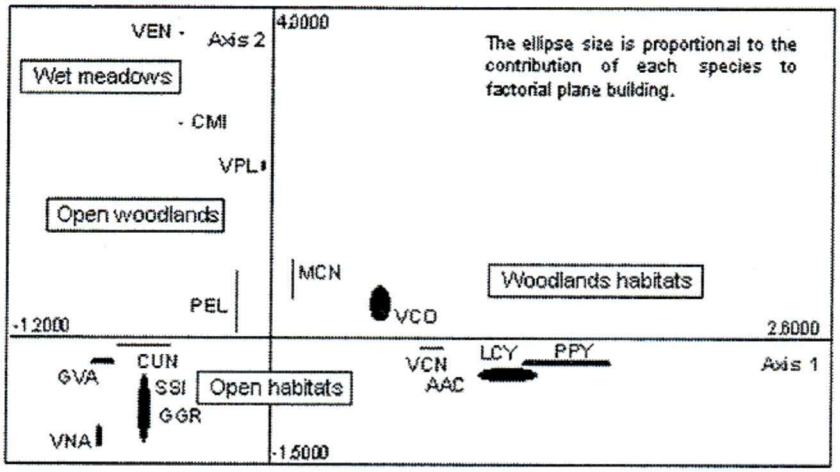
The first axis opposes woodland species (*Punctum pygmaeum, Lauria cylindracea, Vitrea contracta, Vallonia costata, Acanthinula aculeata*) on the positive side, and open-country xerophil species (*Candidula unifasciata, Granaria variabilis, Solatopupa similis, Granopupa granum*) on the negative side. This axis represents a gradient of vegetation closing. This axis orders the samples chronologically with the oldest on the negative side and the most recent on the positive side.

The second axis opposes the species of garrigue and shrubland (*Lauria cylindracea, Granopupa granum, Vitrea narbonensis*) (on the negative side), and some species either of open woods (*Pomatias elegans, Monacha cantiana, Vallonia costata*), or of wet meadows (*Vallonia pulchella, Vallonia enniensis, Carychium minimum*) (on the positive side). As for the samples, it distinguishes, on the positive side, the old layers of parcel 4, almost all of the parcel 6 samples (except for the litter) and all the parcel 3 samples.

The CA reveals, for all the parcels considered, the more or less gradual passage from an open to a forest environment, which expresses quite well the abandonment of land as indicated. In detail, for parcels 1, 4 and 6 there is a very good similarity between the vegetation successions, shown by the land cadastre, and the evolution of the snail composition.

This is not the case for parcel 2, the cadastre indicating "woods" since 1829 whereas land snails show open habitats for the oldest levels, evolving towards open forests and finally a typical forest assemblage only in the upper litter sample. This discrepancy between historical and biological data could be explained by a regular human use, e.g. cuttings of clearance in the coppices of holm-oak, not notified on the land register.

For parcel 3, the local effect could explain the low legibility of the forest development in the molluscan assemblages. Actually, this parcel, now occupied by an open riparian woodland, is located in the bottom of the small valley not far from the brook. This characteristic explains why its assemblages differ from the others, which indicate drier habitats.



AAC : *Acanthinula aculeata* (Müller 1774) ; CMI : *Carychium minimum* (Müller 1774) ; CUN : *Candidula unifasciata rugosiuscula* (Michaud 1831) ; GGR : *Granopupa granum* (Draparnaud 1801) ; GVA : *Granaria variabilis* (Draparnaud 1801) ; LCY : *Lauria cylindracea* (da Costa 1778) ; MCN : *Monacha cantiana* (Montagu 1803) ; PEL : *Pomatias elegans* (Müller 1774) ; PPY : *Punctum pygmaeum* (Draparnaud 1801) ; SSI : *Solatopupa similis* (Bruguière 1792) ; VCN : *Vitrea contracta* (Westerlund 1871) ; VCO : *Vallonia costata* (Müller 1774) ; VEN : *Vallonia enniensis* (Müller 1774) ; VNA : *Vitrea narbonensis* (Clessin 1877) ; VPL : *Vallonia pulchella* (Müller 1774).

Fig. 6. Correspondence Analysis of corrected data from the Tapy valley (living and fresh snails for x.1; "old" shells for x.2, x.3, x.4, x.5, x.6). Plot of the snail species which strongly contribute to the first factorial plane.

The very homogeneous assemblages of parcels 5 and 7 express only weakly the vegetation successions indicated by the land registers. Both these parcels correspond to narrow field terraces on which olive-trees were gardened. The forest overgrowth seems to have been slower, perhaps due to a not very intense but recurrent human use, e.g. gardening.

3.3.2. Taphonomic processes

Paleoenvironmental studies have often been criticised because they have difficulties in taking into account taphonomic processes (intrusion, pollution or absence of age-stratified elements (Carcaillet, 2001). If the seven small sequences from the Tapy valley were studied from a paleoenvironmental point of view, we can wonder whether we could observe the "molluscan horizons" (Barrière, 1964) corresponding to the vegetation successions, or if on the contrary, there would be mixed assemblages.

We, therefore, compared the previously described CA, which takes into account the freshness of the shells, and a CA carried out on the whole data matrix including all the snails, living, fresh or old, i.e. 14,480 shells.

As for the previous CA, the first axis shows a gradient of vegetation closing, the second axis distinguishes open forests and wet meadows. The samples (*Fig. 8*) have a position, which is quite similar to the one they had in the previous CA.

The examination of the position of the assemblages of parcels 5 and 7 in this new analysis confirms what was suggested in the preceding CA: they do not show any more landscape evolution, all samples being grouped towards the open and dry habitats. There is a mixing of the species on account of the recurrence of human disturbances. If these two series of assemblages were included in Holocene sequences, they would show the persistence of an open and dry environment, with a strong human impact, whereas they actually correspond to a gradual land abandonment and a slow but effective forest overgrowth.

4. Applications to a Holocene sequence

The present-day model shows us that terrestrial gastropods are good indicators of post-cultural

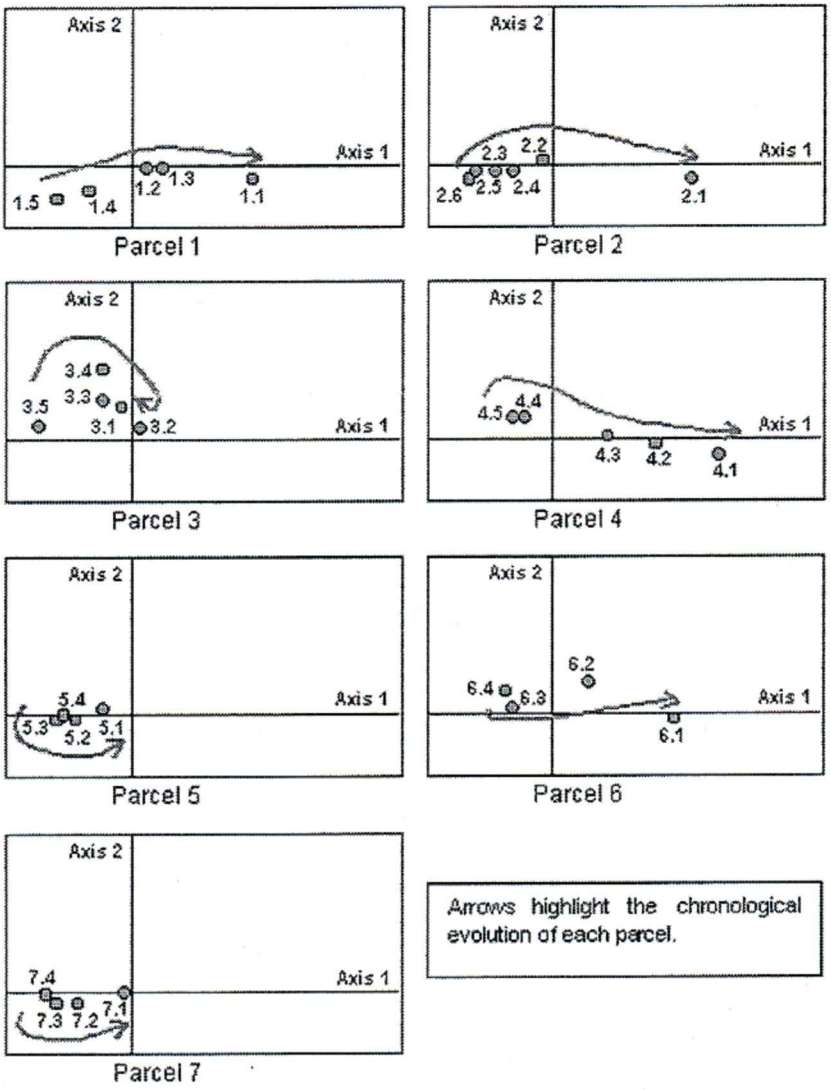


Fig. 7. Evolution of land snail assemblages from the seven parcels from the Tapy valley on the first factorial plane of the CA.

successions and of frequent fires (not so good if the fires are not so frequent) and also that they finely record in the soil horizons the environmental changes that occur over a century. However, the little developed soils of the Tapy valley raise the question of what becomes of these soils after several centuries of evolution and consequently the question of what becomes of the paleoenvironmental information. The evolution of the paleoenvironmental changes is likely to become less legible, because of the taphonomic processes affecting the shells (dissolution, fragmentation, mixing, intrusion) and because of the pedological and geomorphogical processes.

In order to identify the problems of temporal resolution which affect the recording of the environmental changes by the land snail assemblages on a wider scale we will examine a Holocene sequence: the site of the Ubac dolmen.

4.1. Study site

The Holocene Ubac site (Goult, Vaucluse) reveals a succession of human occupations buried in a river terrace: a Middle Neolithic level, a well-preserved Final Neolithic/Chalcolithic dolmen, Bronze Age hearths and Roman walls (*Fig. 9*).

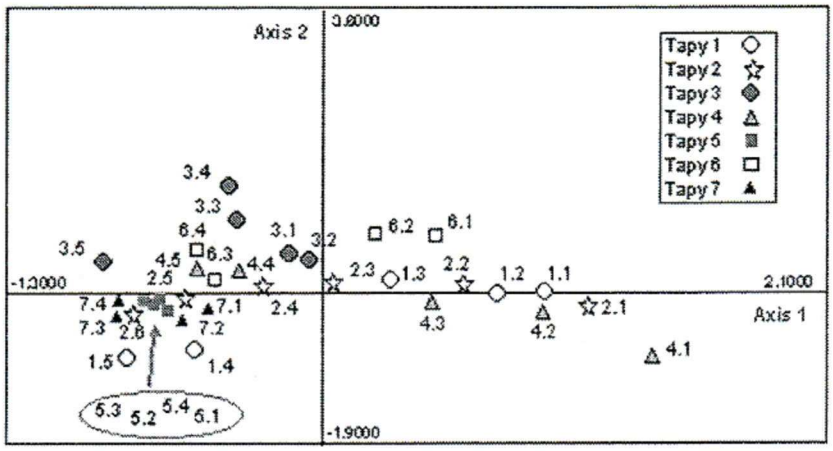


Fig. 8. Correspondence analysis of the whole land snail data of the Tapy valley. Projection of samples on the first factorial plane.

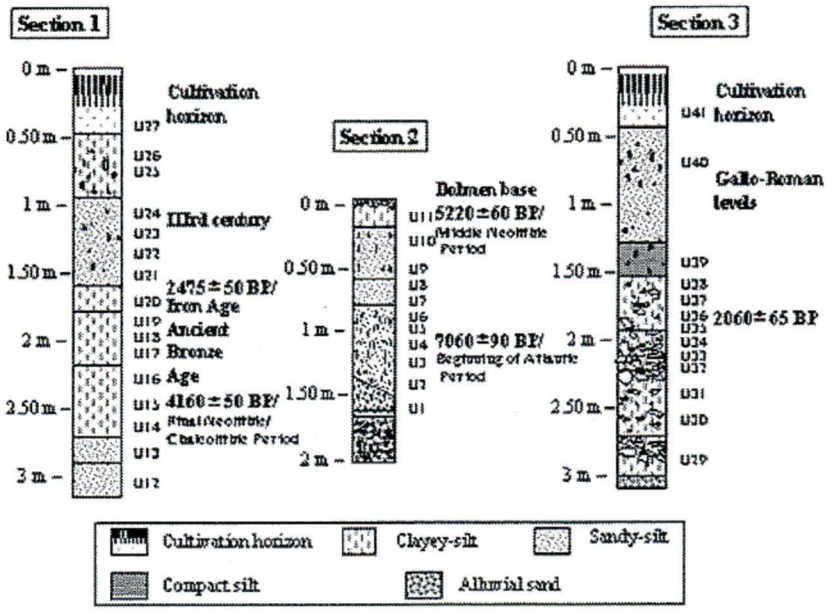


Fig. 9. Stratigraphical sections and dating of the site of the Ubac dolmen (Goult, Vaucluse).

Three sections were sampled for the malacological study: the first under the dolmen; the second outside the archaeological site; the third in a different sedimentary context, closer to the hill-slope (20 m from the dolmen) and characterised by a strong colluvial deposit (Martin and Magnin, 2002).

The sequence can be divided into three great sedimentary units (Brochier, 2000): a first unit, dating from the Mesolithic Age, made up of a detritic deposit altered in its upper part; a second one, until the Protohistorical Period, containing mostly alluvia; a third one, corresponding to the Historical Period, characterised by a colluvial deposit with blown sand.

4.2. Results and discussion

A CA was carried out on all of the samples from the first two profiles (Martin and Magnin, 2002). The first axis of this CA is a gradient of vegetation opening. The second axis specifies the closing rate of forest

habitats. As the first axis presents a very statistically significant gradient, a transfer graph of the co-ordinates of the assemblages on this axis according to chronology thus shows the variations in the vegetation structure along the sequence (*Fig. 10*). The gastropod assemblages show an open forest habitat for the beginning of the Atlantic period. The Middle Neolithic Period is characterised by an opening of this environment, which increases during the Final Neolithic Age. The Bronze Age and Iron Age assemblages are the most closed in the sequence. Finally the Gallo-Roman Period corresponds to a strongly open environment.

Let us consider the different stages of the environmental changes from the point of view of the temporal resolution of gastropod assemblages.

Until the building of the dolmen, the land snails show a low regime of disturbances in accordance with the sedimentological results.

During the final Neolithic/Chalcolithic occupation, the malacofauna recorded an opening of forest formations characteristic of an unquestionable anthropisation. Nevertheless, the presence of forest species could be the consequence of a low human impact on the environment (Martin and Magnin, 2002), perhaps related to a wood-pasture (Brochier, 1984; Kerney et al., 1964).

The Bronze Age and Iron Age levels correspond to woodland assemblages in spite of a human presence attested by archaeology (hearths interpreted as temporary occupations). These levels correspond to a strong increase in erosion related to the increase in disturbances affecting the catchment basin (Brochier, 2000). The terrestrial gastropods would then not record the disturbances affecting probably the vegetation structure during this period. To analyse more finely these particular assemblages, we took, as reference, a present-day landscape in which the heterogeneity had been created by human impact and we attempted to compare some current samples showing various regimes of disturbances and the Holocene samples, in order to observe in which patches of the present-day landscape the best analogues of Holocene assemblages, especially of the protohistorical ones, can be found.

A CA of present-day snail samples collected near to the Ubac site was thus carried out (*Fig. 11*). The CA shows, on the first axis, a gradient of vegetation opening. The second axis distinguishes the types of woodlands: mature and young closing woodlands. The different compositions of the present-day molluscan assemblages are accounted mainly for intensity of the human impact and the time passed since the abandonment of cultivation. As the Holocene assemblages contain the same pool of species as the modern assemblages, they were put in additional elements in the CA. The similarity between the Bronze Age assemblages and the present-day assemblages of young forests can evoke a certain instability of the ecosystems related to a recurrence of human disturbances (Martin and Magnin, 2002). Thus, the woodland protohistorical assemblages express correctly the short and recurring disturbances, which they were subjected to.

A clear break in the composition of the land snail assemblages can be noted between the Iron Age and

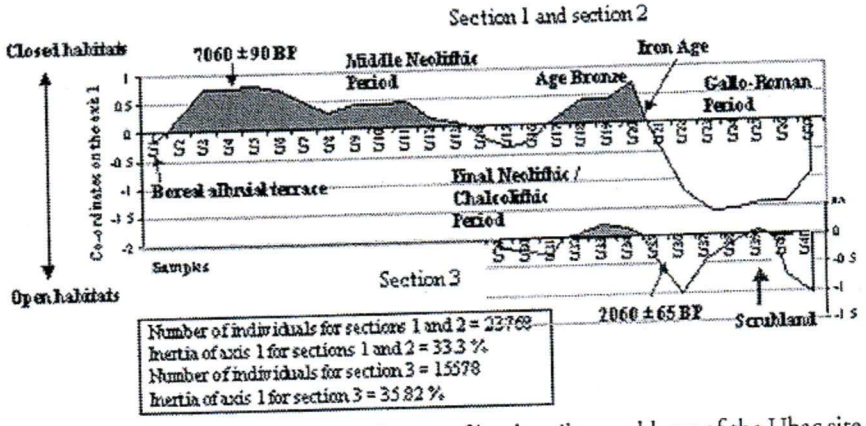


Fig. 10. Transfer graph of the co-ordinates of land snail assemblages of the Ubac site (Goult, Vaucluse) on the first axis of CA, according to stratigraphy.

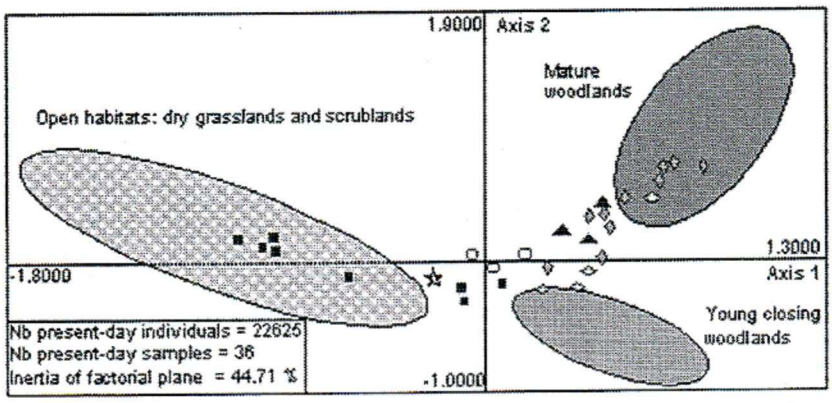


Fig. 11. First factorial plane of the CA done on present-day land snail samples from Goult and Maubec (Vaucluse) (ellipses), with the Holocene Samples from the Ubac site as supplementary passive individuals (symbols : : ☆ Modern Period ; ■ Gallo-roman Period ; ◊ Bronze Age and Iron Age ; ○ Final Neolithic/Chalcolithic Age ; ▲ Middle Neolithic Period ; ♦ Beginning of the Atlantic Period).

the Gallo-Roman Period, which marks the transition-free passage from one to another very contrasted environment (woodlands and dry grasslands). It is also associated with a clear limit between two types of deposits (alluvia then colluvia). Indeed, one can first suppose that the environment opening at the Gallo-Roman period was really sudden and generalised and that a very strong human impact was maintained on the site for a sufficient length of time so that pioneer species could not settle, or that woodland species could not hold. One can also suppose either a threshold effect, or the start of a crisis, both associated with a sedimentary hiatus. This sedimentary hiatus would then not make it possible to observe the more or less gradual passage from woodland to more open assemblages.

For the Gallo-Roman Period, the two previous CA show a drastic opening of the environment, corresponding to the most open assemblages in the sequence, associated with a strong regime of disturbances. However, the comparison of the environmental changes in two different sedimentary contexts (sections 1–3, more colluvial) (*Fig. 10*), points out the presence in the third section of a short phase of abandonment during the Gallo-Roman Period, which can be put in parallel with the present-day model of post-cultural successions. This observation shows the good recording by land snails of the specific environmental changes during the Gallo-Roman period.

The maintenance of open-country assemblages until present times also seems to express a strong and continuous anthropisation during the historical times. However, they are included in a cultural horizon and mixings of several malacological horizons are thus possible, as it is the case for the assemblages from of the Tapy valley parcels 5 and 7.

As a whole, the land snail assemblages of the Ubac site have a rather fine temporal resolution, except when the information is distorted by the taphonomic processes.

5. Conclusion

The malacological analysis is a good tool to finely apprehend the environmental changes in the past, land snails showing a relatively short response time to disturbances and a good correlation with the vegetation successions. The ecology of terrestrial gastropods and the dynamics of the populations are absolutely essential to understand the temporal resolution of the Holocene assemblages. The taphonomic processes which affect at the same time the soils and the molluscan assemblages are complex. Although they appear not question the paleoenvironmental value of assemblages and their stratification, it seems necessary to repeat the experiments in different sedimentary contexts to understand them better (while taking into account, e.g. the preservation of the shells).

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